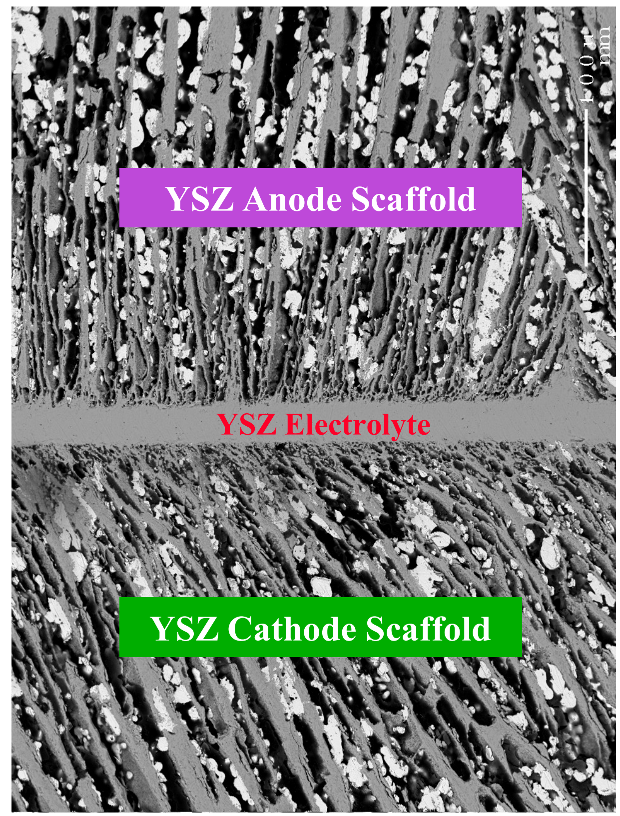
NASA GRC Performance Enhanced SOFC Design

Solid oxide fuel cell (SOFC) systems for aircraft applications require an order of magnitude increase in specific power density under aircraft operating conditions. Further, utilization of hydrocarbon based fuels (jet fuel) requires sufficient tolerance to sulfur under extended exposure and operation. While significant research is underway to develop anode supported SOFC systems operating at temperatures in the range of 650 – 850°C for ground power generation applications, such temperatures may not yield the power densities required for aircraft applications. For electrode-supported cells, SOFC stacks with power densities greater than 1.0 W/cm^2 are favorable at temperatures in excess of 900ºC. In addition to optimizing operation temperature, NASA GRC is evaluating a different approach for increasing specific power densities of SOFC stacks by decreasing the stack weight. Since the interconnect contributes to a significant portion of the stack weight, considerable weight benefits can be derived by decreasing its thickness. Eliminating the gas channels in the interconnect by engineering the pore structure in both anode and cathode can offer significant reduction in thickness of the ceramic interconnect material. Novel solid oxide fuel cells are being developed with porous engineered electrode supported structures with a 10 – 20µm thin electrolyte.

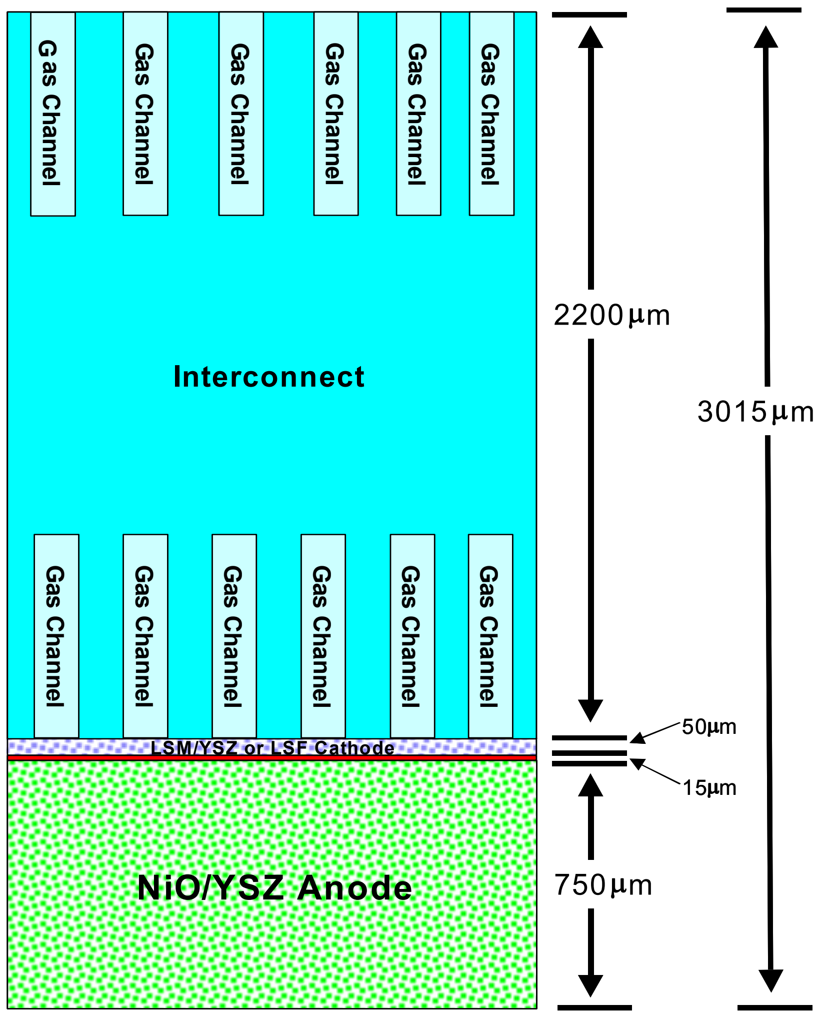
The NASA bi-electrode supported cell (BSC) is symmetrical and thermal expansion matched, providing balanced stresses on each side of the thin electrolyte that can yield high power densities, yet retains favorable mechanical properties for long life operation under significant mechanical vibration and thermal cycling. The porous zirconia support regions are fabricated with graded porosity based on a modified tape casting process that produces a thick support without laminating steps or thermally fugitive pore formers. These engineered microstructures can be optimized for fuel and airflow, while allowing for easier fabrication of the thin electrolyte layer. Since the electrode pore structures contain significant pore gradient to direct gas diffusion, gas channels may not be necessary in the interconnect. Further, the electrodes are infiltrated after the high temperature sintering steps, thus minimizing chemical interaction of active electrodes. This infiltration approach has the key advantage of allowing many new electrode materials not compatible in standard fuel cell systems, particularly those necessary for sulfur tolerance. Since the electrodes support gas diffusion, the interconnect can then be simplified and kept thin, on the order of 20 – 100µm. This reduction of interconnect mass increases the specific power density of the stack, while decreasing the size and cost of the power unit. This design allows for simplified robust stack fabrication and significantly reduced internal resistance. The BSC concept is also applicable to high ionic conductivity mediums including scandia doped zirconia, ceria, and lanthanum gallate based systems.

NASA GRC – BSC Performance Cell



This work is supported under the LEAP project. This innovation was developed by Dr. Thomas L. Cable (QSS Group Inc.) and Dr. Stephen W. Sofie (QSS Group Inc.). NASA point of contact: Dr. Serene Farmer, 216/433-3289, Serene.C.Farmer@nasa.gov

Solid Oxide Fuel Cell - Current State-of-the-Art



Anode Supported Cell (ASC) (*thick anode to provide structural support of the cell*)

- **Advantages:** thin electrolyte for low resistance & high power density, low temperature operation for use with metal interconnects.

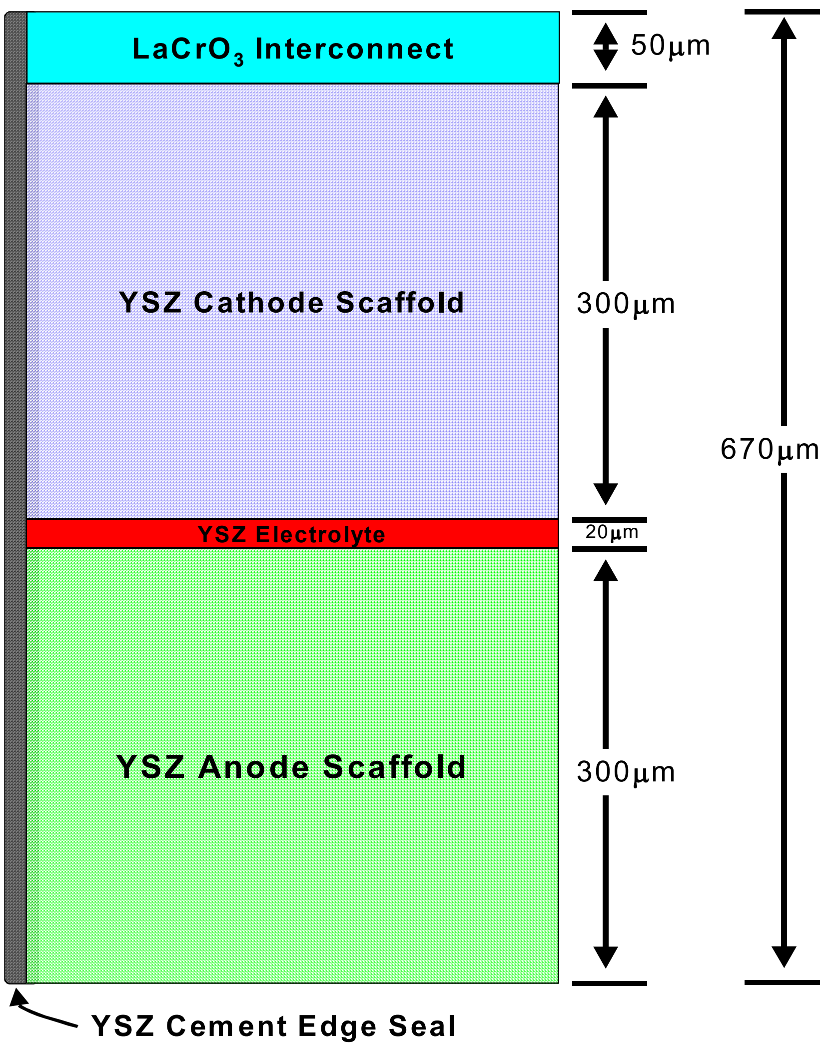
- **Disadvantages:** extremely fragile cells are difficult to manufacture, cells cannot be made perfectly flat for stack assembly, uses thick/heavy metal interconnects.

Repeat Unit: 143 grams

Specific Power Density*: <u>0.28 kW/kg</u>

*based on 400mW/cm^2 single cell output

GRC Advances in Solid Oxide Fuel Cells



Bi-electrode Supported Cell (BSC) *(electrode scaffolds provide structural support of the cell with balance thermal & mechanical stresses)*

•**Advantages:** NASA GRC design uses a thin ceramic interconnect instead of the heavy metal interconnect which is subject to corrosion & high contact resistance

-Zirconia scaffold provides symmetrical stresses on thin electrolyte, larger and flatter parts are easier to fabricate and more robust

-Low temperature application of electrodes allows wider selection of electrode materials for increased performance

-Oxygen-permeable electrolyte, electrode scaffolds, and zirconia cement edge seal are made as one unit, the only way to provide fully hermetic seals

Repeat Unit: 29 grams

Specific Power Density*: 1.37 kW/kg

*based on $400mW/cm^2$ single cell output

BSC Fabrication & Processing

Modified Tape Casting
(Generation of Engineered Porosity)
(Traditional Tape Casting with Thermally Fugitive Pore Formers is also utilized)

Punching Green Tapes
(Electrode Scaffolds)

Application of Thin Electrolyte
(Screen Printing – Air Brushing)

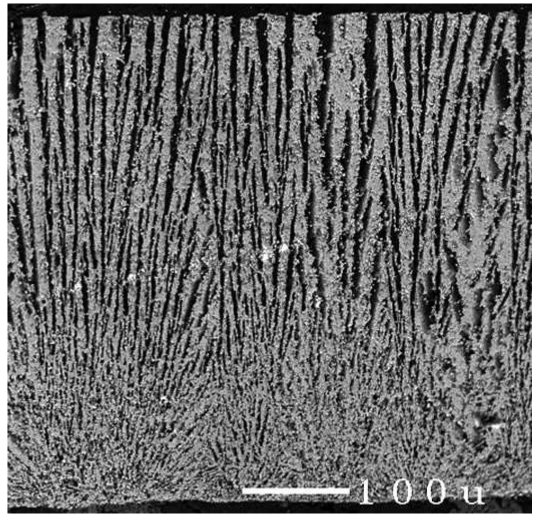
Lamination of Green Tapes
(Solvent Bond – no heat or pressure)

Sintering of BSC
(High Temperature Processing)

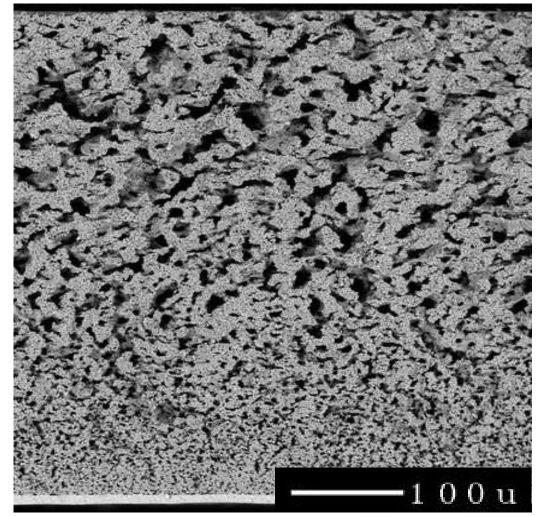
Infiltration of Electrodes
(Solution, Slurry, or Vapor Coating)

In-situ Consolidation of Electrodes
(Max. Cell Operating Temp.)

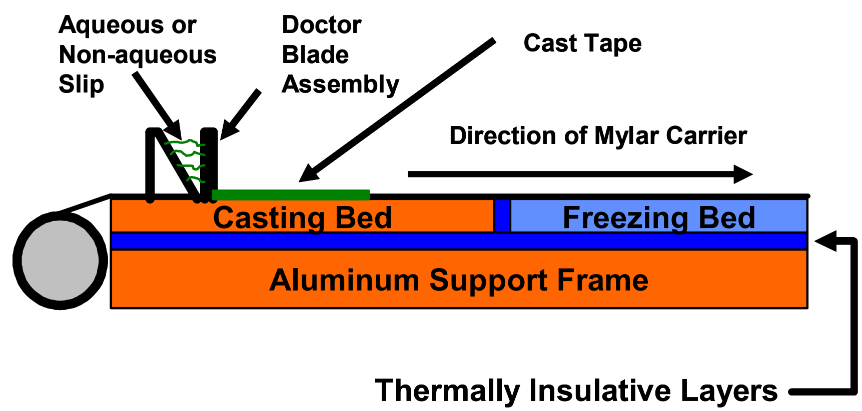
NASA Developed Processing Techniques



Freeze Tape Casting



Coagulation Tape Casting



Single Processing Step to Create Graded/Aligned Pores

No Thermally Fugitive Additives